COLLEGE DOCTORAL PAYS DE LA LOIRE | ED MATIERE MOLECULES MATERIAUX & GEOSCIENCES

DESCRIPTION D'UN PROJET DE THÈSE FINANCÉ - ÉCOLE DOCTORALE « Matière, Molécules, Matériaux & Géosciences »

INFORMATIONS GÉNÉRALES

Titre de la thèse : Martian Ice Distribution and Dynamics - Répartition et dynamique de la Glace sur Mars (M/W)
Champ disciplinaire 1 : Planétologie **Champ disciplinaire 2 : Géomorphologie**
Trois mots-clés : Mars, ISRU, glace d'eau
Unité d'accueil (préciser si temps partagé entre plusieurs sites) : Laboratoire de Planetologie et Geosciences
Nom, prénom du directeur de thèse (HDR indispensable) : CONWAY, Susan **Adresse mail :** susan.conway@univ-nantes.fr **Nom, prénom du co-directeur (le cas échéant) (HDR indispensable) :** **MANGOLD, Nicolas** **Adresse mail : nicolas.mangold@univ-nantes.fr** **Nom, prénom du co-encadrant de thèse 1 (le cas échéant) : GRAU GALOFRE, Anna** **Adresse mail : anna.graugalofre@univ-nantes.fr** **Nom, prénom du co-encadrant de thèse 2 (le cas échéant) : BYRNE, Shane** **Adresse mail :**
Contact(s) (adresse postale) : Université de Nantes - UFR Sciences et Techniques, 2 rue de la Houssinière, F-44000 NANTES

Une fois complété, merci d'enregistrer ce document au format pdf avec le nom suivant :Nom du Directeur thèse_Unité.pdf

DESCRIPTION SCIENTIFIQUE DU PROJET DE THÈSE

Description du sujet : contexte, objectifs, méthodologie (1 page maximum)

The search for water on Mars has been the focus of many spacecraft missions, both orbital and landed. Understanding the nature and distribution of water ice is fundamental for the understanding of current and recent climate, and ice as a resource for human exploration. Water ice is present at the surface in both polar caps, and at high latitudes (>60°N) where it is detected near the surface by neutron spectrometry and landforms such as patterned ground (e.g., Feldman et al., 2002, Mangold et al., 2004). Water ice in the mid-latitudes (30-60°) is shown to be present from direct observations (such as radar data, Holt et al., 2008), local ice outcrops (Dundas et al. 2018, 2021), new impact craters revealing ice (Byrne et al. 2009; Dundas et al. 2010, 2021) and landforms such as debris covered glaciers or "viscous flow features" (VFF) (e.g., Levy et al. 2014). However, in the mid-latitudes, the depth to this water ice remains largely unconstrained. The lack of detection in Neutron Spectrometer data suggests depths >1 m; however, ice excavated by new impacts and local water ice outcrops (Dundas et al. 2018, 2021; Harish et al. 2020) suggest that ice could be nearer the surface locally.

The presence of near-surface ice is a critical resource for future human exploration (Morgan et al. 2021). Water ice is easily accessible in the polar regions (>60°), yet these regions are extremely cold with the formation of CO_2 frost (at -130°C) in winter, as well as having periods with little or no sunlight to provide solar energy. Equatorial regions are thermally favorable, but there is no water ice at or near the surface. Hence, the mid-latitudes (typically 30-60° N or S) are a good compromise between access to water ice and environmental conditions that are manageable for human exploration. Yet, the depth at which ice is present and its purity or contamination by salts or debris is poorly constrained. Both questions have a strong impact on where the first human base could be built with a guarantee of finding water easily. Thus, we aim to study the distribution of water ice in the mid-latitudes coupling a systematic survey from images, monitoring, morphological investigations with Digital Terrain Models (DTMs), and numerical modeling. The focus of our joint study will be steep pole-facing scarps that expose water ice (Dundas et al. 2018, 2021; Harish et al. 2020), which are thought to be constrained to latitudes of 50-60° in both hemispheres (but we will search for ones at lower latitude, Fig. 1a) and martian debris covered glaciers, hereafter called VFF or "Viscous Flow Features", which are common between 30° and 60° latitude. This project will benefit from HiRISE (High Resolution Imaging Experiment) and CaSSIS (Colour and Stereo Surface Imaging System) data, with privileged access for the student that stem from the PIs' involvement in these missions.

Objectives:
We aim to study the distribution of water ice in the mid-latitudes coupling a systematic survey from images, monitoring, morphological investigations with Digital Terrain Models (DTMs), and numerical modelling.

Méthodologie:

Scarp Survey: 34 localities with ice-exposing scarps were mapped by Dundas et al. (2021) using THEMIS Daytime Infrared controlled mosaics at 100 m/pixel (Fig. 1c) and hence we propose to use MRO Context (CTX) camera images with global coverage at 6 m/pixel to search for smaller examples that would not be easily identifiable at 100 m/pixel. To confirm whether they expose ice, color images with CaSSIS and HiRISE will be planned and complemented with hyperspectral data from Compact Reconnaissance Imaging Spectrometer for Mars (CRISM) where available. DTMs will be used to determine: the thickness of the ice deposit, the steepness and shape of the exposure, and the insolation conditions experienced by the scarp (through calculation based on measured slope, aspect, and latitude). We will estimate the volume lost from the cavities hosting the icy scarps by differencing the DTM with an uncertainty-aware estimate of the initial topography. This initial topography will be produced by adapting Conway and Balme (2014). We will examine the datasets for trends in shape/size/orientation of the scarps with latitude and longitude, elevation and thermal inertia to assess if this corresponds with our expectations based on known climate variables. In combination with information from the DTMs in we will address the open question of how these scarps evolve with time.
Mapping VFF. We will use the database of tongue-like VFF compiled by Souness et al. (2012) (Fig. 1c) to identify tens of locations where stereo images exist to make DTMs and will perform VFF detailed mapping using GIS software to constrain the models utilized by the student in Arizona. This mapping will record key features that indicate the transport direction/rate and stress state of the ice, including crevasses (Hubbard 2014; Brough et al. 2016), debris bands (Levy et al. 2021), and deformed craters (Kress and Head, 2008). We will use CaSSIS color images to search for distinctive signatures from the debris carried in the ice and search for serendipitous incisions into the VFF where information on the internal stratigraphy could be obtained (Butcher et al. 2021).
The VFF we will study are too small to have their basal topography estimated from RADAR data so we rely on our

stereo DTMs to estimate this. Basal topography is a required input to for modelling by the Arizona student and is also used with the DTM to estimate ice thickness. To estimate basal topography we extrapolate the valley wall beneath the remnant glacial features as previously performed by Levy et al. (2014), but adapting to the latest techniques used on Earth (Mey et al. 2015). Extrapolation of surrounding topography has been shown to agree with RADAR basal reflections of debris covered glaciers.

Compétences scientifiques et techniques requises pour le candidat :

The candidate should have a masters in planetary sciences or the geosciences. They should already have some experience in the acquisition, manipulation and analysis of remotely sensed image and topographic datasets, preferably on Mars, or other planetary bodies. Experience in programming would be a benefit. A good level of written and spoken English is required for collaboration with the project partners in Arizona. The candidate should demonstrate an enthusiasm for planetary exploration.

Please, apply on the CNRS plateform : https://emploi.cnrs.fr/ until 15/06/23

OFFER : UMR6112-SOPHUG-003

ENCADREMENT DE LA THÈSE[1]

Nom de l'unité d'accueil : Laboratoire de Planétologie et Géosciences CNRS UMR 61112	**Nom de l'équipe d'accueil :** Nous n'avons pas des équipes au laboratoire
Nom du directeur de l'unité : LANGLAIS, Benoit	**Nom du responsable de l'équipe :** Nous n'avons pas des équipes au laboratoire
Coordonnées du directeur de l'unité : benoit.langlais@univ-nantes.fr	**Coordonnées du responsable de l'équipe :** Nous n'avons pas des équipes au laboratoire
Directeur de thèse **Nom, prénom** : CONWAY, Susan **Fonction** : Chargée de recherche CNRS **Date d'obtention de l'HDR** : 6 mars 2023, Nantes Universite **Employeur** : CNRS **Taux d'encadrement doctoral dans le présent sujet** : 40% **Taux d'encadrement doctoral en cours (directions et co-directions)** : 1 direction (qui se termine en juillet 2023) a 40% **Nombre de directions/co-directions de thèse en cours** : 1	
Co-directeur (le cas échéant) **Nom, Prénom :** MANGOLD, Nicolas **Fonction :** Directeur de recherche CNRS	

[1] Dans l'ED 3MG, si 1 scientifique dans la direction de la thèse = 100% d'encadrement doctoral ; si 2/3 personnes impliquées dans l'encadrement de la thèse, un taux de 40% minimum est exigé pour l'HDR directeur et 30% pour les autres encadrants.

Date de l'obtention de l'HDR : aout 2007 à Univ Paris Sud

Employeur : CNRS

École doctorale de rattachement : 3MG

Taux d'encadrement doctoral dans le présent projet : 20%

Taux d'encadrement doctoral en cours (directions/co-directions/co-encadrements):

40% en directeur x 2

Nombre de directions/co-directions/co-encadrements de thèse en cours : 2

Co-encadrant de thèse 1 (le cas échéant)

Nom, prénom : GRAU GALOFRE, Anna

Fonction : Chargée de recherche CNRS

Titulaire de l'HDR : ☐non Si oui, date d'obtention de l'HDR :

Employeur : CNRS

École doctorale de rattachement : 3MG

Taux d'encadrement doctoral dans le présent projet : 30%

Taux d'encadrement doctoral en cours (directions/co-directions/co-encadrements): 10% un étudiante et 50% l'autre

Nombre de directions/co-directions/co-encadrements de thèse en cours : 2

Co-encadrant de thèse 2 (le cas échéant)

Nom, prénom : BYRNE, Shane

Fonction : Professor

Titulaire de l'HDR : ☐non Si oui, date d'obtention de l'HDR :

Employeur : University of Arizona

École doctorale de rattachement : University of Arizona

Taux d'encadrement doctoral dans le présent projet : 10%

Taux d'encadrement doctoral en cours (directions/co-directions/co-encadrements) : 10% per étudiant

Nombre de directions/co-directions/co-encadrements de thèse en cours : 8

FINANCEMENT DE LA THÈSE

Origine(s) du financement de la thèse : CNRS 80PRIME (CNRS – UArizona) Apply on the CNRS platform: https://emploi.cnrs.fr/ OFFER NUMBER: UMR6112-SOPHUG-003
Montant brut mensuel : 2135 €
État du financement de la thèse : financé
Date du début/durée du financement de la thèse : 1er octobre 2023